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Guest Editorial

Image guidance in the radiotherapy treatment room: Can ten years of rapid development prepare us for the future?

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It is exciting to see the *Journal of Radiotherapy in Practice* (JRP) grow and flourish – there is no doubt it fills an important niche. This is not a surprise as radiotherapy itself is growing while its treatment practice has undergone dramatic changes over the past 10 years. There appear to be two key drivers for this change: an increased focus on the patient's interests and a more sophisticated use of technology. JRP has set out to play an important role in publishing articles on both these topics (and a lot more).[1] Although this editorial focuses on the technology aspect, it is understood that the use of technology is only warranted if patients benefit from it in the end.

There is no doubt that practitioners and researchers in the field of radiotherapy practice are not twiddling thumbs. They are actively engaging with technology and are aware of its importance as demonstrated in recent survey by Cox, which showed that Australian radiation therapists considered technology-related research as the most important to radiation therapy.[2]

The dramatic change in technology which has taken place over the past 10 years results in the ability to deliver more conformal dose distributions using techniques such as intensity-modulated radiation therapy (IMRT).[3] It also brings high-quality imaging in an increasing number of treatment rooms.[4,5] After radiology and radiotherapy have been drifting apart for years they seem to come closer together again.

The impact of technology on radiotherapy practice and the role of its practitioners can be seen nowhere clearer than in the widely available imaging tools in the treatment room, often described by the term image-guided radiation therapy (IGRT).[6,7]

Unfortunately, the term IGRT is not as clearly defined as IMRT where the International Commission on Radiological Units and Measurements provides a very broad definition in its recent report 83.[8] However, it is common to limit the term to images acquired in the treatment room as opposed to imaging in treatment planning. This is also echoed in a literature review of computed tomography (CT) for image guidance in this issue of JRP.[9] Admittedly, there is some overlap as images acquired during treatment can trigger changes in treatment plan and/or approach, often called adaptive radiotherapy.[10–12]

Figure 1 illustrates where IGRT is placed in the overall context of radiotherapy with the aim is to achieve loco-regional tumour control. The identification and definition of the target has improved dramatically over the last years with magnetic resonance imaging (MRI) and positron emission tomography becoming available or at least accessible in many clinics.[13,14] Also the delivery of radiation has become more sophisticated, mostly through the availability of IMRT[3,15] and more recently volumetric modulated arc therapy.[16] This leaves a last task to accomplish – the need to deliver the

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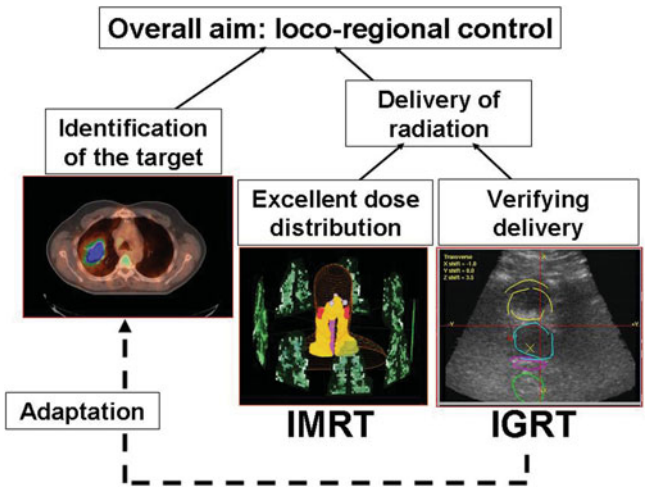

Figure 1. The role of IMRT and IGRT in the context of radiotherapy.

complex dose distributions achievable with IMRT to the correct location. This activity, IGRT, is one of the key responsibilities of treatment staff and will affect the daily work of many readers of JRP.

In the context of Figure 1, it is interesting to note that IMRT with its steep dose gradients is always likely to benefit from image guidance; however, the opposite is not necessarily correct as all treatment deliveries can benefit from IGRT. One can actually argue that in some circumstances a simple and fast treatment can make better use of an image-guided approach, as the images acquired prior to treatment are more likely to reflect the anatomy as the treatment is delivered.

IGRT relies on the availability of high-quality imaging in an increasing number of treatment rooms. The variety of imaging tools is mind-boggling ranging from electronic portal imaging[17] to diagnostic kV imaging,[18] ultrasound[19] and varieties of CT scanning.[20,21]

There is no clear delineation between conventional verification imaging and IGRT; however, it is generally assumed that IGRT pertains to the frequent visualisation of the target itself, an important critical structure or a suitable surrogate marker. As such bony anatomy or surface imaging using optical methods[22] would only qualify if the bones or skin are directly related to the treatment objective. On the other hand, IGRT does not necessarily require daily imaging as it is often sufficient to reduce a systematic error between planning and treatment to optimise delivery.[23] On the other hand IGRT may require the acquisition of more than one image per treatment session, for example, for motion management[24] or in the case of a prolonged delivery not uncommon in hypofractionated treatments.[25]

However, an important distinction in the field of IGRT from a practical perspective is online versus offline decision making. It is obvious that different clinical scenarios require different approaches to decision making. In many instances the determination of a systematic problem offline can be the most effective way to reduce treatment error. As most of radiotherapy is delivered in many fractions, a systematic error for example in patient set-up due to differences between planning and treatment affects all fractions. Systematic errors therefore are the largest contributor to margins[26] and several methods have been proposed to eliminate them after reviewing images from the first fractions offline.[27] A systematic error can also result from changing patient or tumour geometry – in this case imaging can detect the change and prompt re-planning of the treatment.[10]

In other clinical scenarios day to day variations dominate the treatment uncertainty. In this case daily imaging is required and operators have to make decisions online with the patient

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on the treatment couch. This decision-making can be simple such as the movement of the patient based on fiducial markers implanted in the target.[21]

However, it can also involve more complex decision making such as selection of the best plan for the day based on a number of plans.[28]

In any case, the availability of high-quality image information of the patient at the treatment unit prior or during treatment has several important implications for radiotherapy practice:

1. IGRT allows the assessment of our current practice. This can be a sobering or re-assuring process. In any case, it allows for reflection on and improvement of practice. Another interesting aspect of this new understanding of current practice is that it can help to interpret clinical results obtained in the past and therefore substantiate clinical evidence.
2. IGRT allows modification of treatment approaches with tighter margins[29] and the possibility of dose escalation[30] often achieved through significant hypofractionation.[25]
3. IGRT provides scope for modification of the treatment plan during the course of treatment based on the image guidance. This process, often termed adaptive radiotherapy can be performed offline or online. If the 'adaptation' is to be performed online it places a lot of additional responsibility on treatment staff even if one only has to choose the most appropriate treatment plan from a number of options.[28]
4. IGRT changes the role and responsibilities of the treatment staff who have to interpret images on the spot and make complex decisions under time pressure. It is important that an independent check by another competent professional is available. This needs to be considered when deciding on staffing numbers.
5. IGRT requires additional training. This applies not only to the operation of the imaging equipment but also to the interpretation of the images.[31]
6. IGRT requires new quality assurance activities such as the checking of image quality and the verification of spatial accuracy.[5,32] It may also require a completely new approach to multidisciplinary quality assurance as discussed at a recent symposium.[33] These checks are often required daily and as such will involve radiotherapy staff.
7. IGRT provides new challenges and hopefully more confidence for radiation therapy staff. One of the challenges will be role extension as treatment staff are faced with the task of interpreting complex image information. However, this can also improve job satisfaction which is important in a profession where staff retention is not always easy.[34]
8. IGRT provides ample opportunity for research. This ranges from research into operational aspects of imaging and decision making to assessment of immobilisation.[35] On the other hand, IGRT also improves clinical research as it ensures accuracy of delivery – there is assurance that what you see is what you get and many clinical trials nowadays require some form of image guidance.
9. IGRT introduces new benefits and costs into radiotherapy, which need to be managed. These may be health economic considerations;[36] however, it could also be the more general investigation of risks and benefits to the patient due to IGRT. A typical example is the additional dose received by the patient due to imaging which must be balanced against improved treatment delivery.[37]

This list cannot be exhaustive but helps to illustrate the breadth of the change brought to radiotherapy practice by the introduction of new technology in general and specifically IGRT. While these changes are currently taking place it is important to plan for the future to optimise the utilisation of technology, provide appropriate training and meet the expectations of clinicians and increasingly also of patients. Where will we be in another 10 years time? This is difficult to predict, as change is not a linear process. However, one can assume

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that imaging will be important in several aspects. For example functional imaging and improved soft tissue contrast will provide even better visualisation of the target, for example with MRI becoming available in the treatment room.[38] The availability of images throughout the treatment course provides new diagnostic information that can be used to predict treatment outcome. It also allows early analysis of treatment response with the opportunity to adapt the treatment appropriately.[12,39,40] It can also be anticipated that computer tools such as deformable registration, automatic contouring and pattern recognition will help users to make the most of the technology. Finally, sophisticated databases can be expected to support our clinical research and provide clinicians and patients with decision-making aids to find the best possible treatment approach for an individual patient.

In any case it is important that change and future developments are informed by practice and not just by technological capabilities. Journals such as JRP have an important role to play here and it is not surprising to see two articles concerned with IGRT in the present issue of JRP.[9,41] They show that image guidance is here to stay: it intuitively makes sense as a method to improve radiotherapy – the evidence is emerging that this intuition is leading into the right direction.

References

1. Wu V, Ho M, Yuen L *et al.* Comparison of verification accuracy and radiation dose between megavoltage CT and kilovoltage cone-beam CT. J Radiother Pract 2011; 10:35–44.
2. Cox J, Halketta G, Andersona C *et al.* Australian radiation therapists rank technology-related research as most important to radiation therapy. J Radiother Pract, Available on CJO 2011 doi:1017/S1460396910000464.
3. Webb S. Intensity-modulated radiation therapy (IMRT): a clinical reality for cancer treatment, "any fool can understand this". The 2004 Silvanus Thompson Memorial Lecture. Br J Radiol 2005; 78(Spec No 2):S64–S72.
4. Dawson LA, Jaffray DA. Advances in image-guided radiation therapy. J Clin Oncol 2007; 25:938–946.
5. Korreman S, Rasch C, McNair H *et al.* The European Society of Therapeutic Radiology and Oncology-European Institute of Radiotherapy (ESTRO-EIR) report on 3D CT-based in-room image guidance systems: a practical and technical review and guide. Radiother Oncol 2010; 94:129–144.
6. van Herk M. Different styles of image-guided radiotherapy. Semin Radiat Oncol 2007; 17:258–267.
7. Verellen D, De Ridder M, Storme G. A (short) history of image-guided radiotherapy. Radiother Oncol 2008; 86: 4–13.
8. ICRU. ICRU report 83: Prescribing, recording, and reporting of IMRT. ICRU reports. Bethesda: International Commission on Radiological Units and Measurements, 2010.
9. Fung WW, Cheung W. Image-guided radiation therapy using computed tomography in radiotherapy. J Radiother Pract 2011; 10:121–136.
10. Tanyi JA, Fuss MH. Volumetric image-guidance: does routine usage prompt adaptive re-planning? An institutional review. Acta Oncol 2008; 47:1444–1453.
11. Song W, Schaly B, Bauman G, Battista J, Van Dyk J. Image-guided adaptive radiation therapy (IGART): Radiobiological and dose escalation considerations for localized carcinoma of the prostate. Med Phys 2005; 32:2193–2203.
12. Mageras GS, Mechalakos J. Planning in the IGRT context: closing the loop. Semin Radiat Oncol 2007; 17:268–277.
13. Kruser TJ, Bradley KA, Bentzen SM *et al.* The impact of hybrid PET-CT scan on overall oncologic management, with a focus on radiotherapy planning: a prospective, blinded study. Technol Cancer Res Treat 2009; 8: 149–158.
14. Dawson LA, Sharpe MB. Image-guided radiotherapy: rationale, benefits, and limitations. Lancet Oncol 2006; 7:848–858.
15. Hartford AC, Palisca MG, Eichler TJ *et al.*; American Society for Therapeutic Radiology and Oncology; American College of Radiology. American Society for Therapeutic Radiology and Oncology (ASTRO) and American College of Radiology (ACR) Practice Guidelines for Intensity-Modulated Radiation Therapy (IMRT). Int J Radiat Oncol Biol Phys 2009; 73:9–14.
16. Otto K. Volumetric modulated arc therapy: IMRT in a single gantry arc. Med Phys 2008; 35:310–317.
17. Herman MG. Clinical use of electronic portal imaging. Semin Radiat Oncol 2005; 15:157–167.
18. Ding GX, Duggan DM, Coffey CW. Characteristics of kilovoltage x-ray beams used for cone-beam computed tomography in radiation therapy. Phys Med Biol 2007; 52:1595–1615.
19. Cury FL, Shenouda G, Souhami L *et al.* Ultrasound-based image guided radiotherapy for prostate cancer: comparison of cross-modality and intramodality methods for daily localization during external beam radiotherapy. Int J Radiat Oncol Biol Phys 2006; 66:1562–1567.

https://doi.org/10.1017/S1460396911000215 Published online by Cambridge University Press

20. Jaffray DA, Siewerdsen JH, Wong JW, Martinez AA. Flat-panel cone-beam computed tomography for image-guided radiation therapy. Int J Radiat Oncol Biol Phys 2002; 53:1337–1349.
21. Owen R, Foroudi F, Kron T *et al*. A comparison of in-room computerized tomography options for detection of fiducial markers in prostate cancer radiotherapy. Int J Radiat Oncol Biol Phys 2010; 77:1248–1256.
22. Brahme A, Nyman P, Skatt B. 4D laser camera for accurate patient positioning, collision avoidance, image fusion and adaptive approaches during diagnostic and therapeutic procedures. Med Phys 2008; 35:1670–1681.
23. van Herk M. Errors and margins in radiotherapy. Semin Radiat Oncol 2004; 14:52–64.
24. Keall PJ, Mageras GS, Balter JM *et al*. The management of respiratory motion in radiation oncology report of AAPM Task Group 76. Med Phys 2006; 33:3874–3900.
25. Timmerman RD, Kavanagh BD, Cho LC, Papiez L, Xing L. Stereotactic body radiation therapy in multiple organ sites. J Clin Oncol 2007; 25:947–952.
26. van Herk M, Remeijer P, Rasch C, Lebesque JV. The probability of correct target dosage: dose-population histograms for deriving treatment margins in radiotherapy. Int J Radiat Oncol Biol Phys 2000; 47:1121–1135.
27. Wratten CR, Denham JW, Kron T, O'Brien P, Hamilton CS. 'When measurements mean action' decision models for portal image review to eliminate systematic set-up errors. Australas Radiol 2004; 48:272–279.
28. Foroudi F, Wong J, Kron T *et al*. Online Adaptive Radiotherapy for Muscle-Invasive Bladder Cancer: Results of a Pilot Study. Int J Radiat Oncol Biol Phys; 2010 Oct 5. Epub ahead of print.
29. Skarsgard D, Cadman P, El-Gayed A *et al*. Planning target volume margins for prostate radiotherapy using daily electronic portal imaging and implanted fiducial markers. Radiat Oncol 2010; 5:52.
30. Ghilezan M, Yan D, Liang J *et al*. Online image-guided intensity-modulated radiotherapy for prostate cancer: How much improvement can we expect? A theoretical assessment of clinical benefits and potential dose escalation by improving precision and accuracy of radiation delivery. Int J Radiat Oncol Biol Phys 2004; 60:1602–1610.
31. Foroudi F, Wong J, Kron T *et al*. Development and evaluation of a training program for therapeutic radiographers as a basis for online adaptive radiation therapy for bladder carcinoma. Radiography 2010;16:14–20.
32. Thwaites DI, Verellen D. Vorsprung durch Technik: evolution, implementation, QA and safety of new technology in radiotherapy. Radiother Oncol 2010;94:125–128.
33. Williamson JF, Dunscombe PB, Sharpe MB *et al*. Quality assurance needs for modern image-based radiotherapy: recommendations from 2007 interorganizational symposium on "quality assurance of radiation therapy: challenges of advanced technology". Int J Radiat Oncol Biol Phys 2008; 71:S2–12.
34. Probst H, Griffiths S. Retaining therapy radiographers: What's so special about us? J Radiother Pract 2006; 6:21–32.
35. Velec M, Waldron JN, O'Sullivan B *et al*. Cone-beam CT assessment of interfraction and intrafraction setup error of two head-and-neck cancer thermoplastic masks. Int J Radiat Oncol Biol Phys 2010; 76:949–955.
36. Bentzen SM. High-tech in radiation oncology: should there be a ceiling? Int J Radiat Oncol Biol Phys 2004; 58:320–330.
37. Kron T, Wong J, Rolfo A *et al*. Adaptive radiotherapy for bladder cancer reduces integral dose despite daily volumetric imaging. Radiother Oncol 2010; 97:485–487.
38. Lagendijk JJ, Raaymakers BW, Raaijmakers AJ *et al*. MRI/linac integration. Radiother Oncol 2008; 86:25–29.
39. Guckenberger M, Richter A, Wilbert J, Flentje M, Partridge M. Adaptive radiotherapy for locally advanced non-small-cell lung cancer does not underdose the microscopic disease and has the potential to increase tumor control. Int J Radiat Oncol Biol Phys; 2011 Apr 14. Epub ahead of print.
40. Everitt S, Hicks RJ, Ball D *et al*. Imaging cellular proliferation during chemo-radiotherapy: a pilot study of serial 18F-FLT positron emission tomography/computed tomography imaging for non-small-cell lung cancer. Int J Radiat Oncol Biol Phys 2009; 75:1098–1104.
41. Sale C, ffrench T, Voss R. Personalising margins for bladder radiotherapy. J Radiother Pract 2011; 10:137–140.

https://doi.org/10.1017/S1460396911000215 Published online by Cambridge University Press